

THE NUMBERS OF MARBLED MURRELETS IN WASHINGTON MARINE WATERS

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Abstract. Marbled Murrelets (*Brachyramphus marmoratus*) were censused during several field studies of bird use of Washington marine waters, during various seasons and times between 1971 and 1985. Using results from different studies that used different methods, summer and winter populations are discussed. The best estimate of Marbled Murrelet abundance in Washington coastal waters is a total of about 5000 birds present during the spring-summer (April–July) breeding season. Winter data are less complete, though limited anecdotal reports, and qualitative and quantitative observations, suggest numbers are larger at that season than during the summer.

Key words: *Brachyramphus marmoratus*; *Marbled Murrelet*; *marine waters*; *populations*; *Washington*.

INTRODUCTION

The nominate subspecies of the Marbled Murrelet (*Brachyramphus m. marmoratus*) breeds along the Nearctic continental margin from Alaska to central California (AOU 1957) and winters in the same area. Estimates of densities and numbers of murrelets at sea have been made in Alaska (Sowls et al. 1978), British Columbia (Vermeer et al. 1983, Carter 1984, Sealy and Carter 1984), Washington (Wahl et al. 1981, Wahl and Speich 1984, Speich and Wahl 1989), and California (Sowls et al. 1980). Most data were collected incidental to seabird colony surveys and therefore are incomplete; only along part of the west coast of Vancouver Island, British Columbia, have surveys been conducted specifically to census murrelets (Carter 1984, Sealy and Carter 1984). In this paper, we collate data from several sources to determine the distribution and estimate the numbers of Marbled Murrelets present in all marine waters of Washington year round (i.e., during the breeding and non-breeding periods).

METHODS

Censuses

Marbled Murrelets in nearshore (<20 m deep) coastal waters were observed and counted with

a 20× telescope in 1984 and 1985 from three shore stations on the outer coast (Speich et al. 1987; Fig. 1): Sea Lion Rock, in a 40° arc extending from shore about half way (2.4 km) to Sea Lion Rock (total area surveyed 2.0 km²); Willoughby Rock, in an 80° arc from shore 2.3 km to Split Rock (total area surveyed 3.7 km²); and Point Grenville, in a 120° arc from shore 1.1 km to Grenville Arch (total area surveyed 1.2 km²). Numbers recorded at each location were summed and divided by the area surveyed on all censuses during each week to obtain bird densities (birds/km²).

During June and July of 1978, 1979, and 1985, 11 boat transects were made through various stretches of coastal nearshore waters (Table 1). Murrelets were counted out to 150 m on one or (usually) both sides of an inflatable boat. Numbers of Marbled Murrelets were divided by the area surveyed on each transect to obtain densities.

Only one set of winter observations of the nearshore coastal waters of the outer coast has been quantified. On 19 November 1979, an aerial survey was flown from Cape Flattery to the mouth of Grays Harbor and return (330 km length, 39.6 km² surveyed) using standard methods described in Wahl et al. (1981), Wahl and Speich (1984), and Speich and Wahl (1986). An aerial survey of the Columbia River and nearshore waters in this vicinity on 13 April 1984

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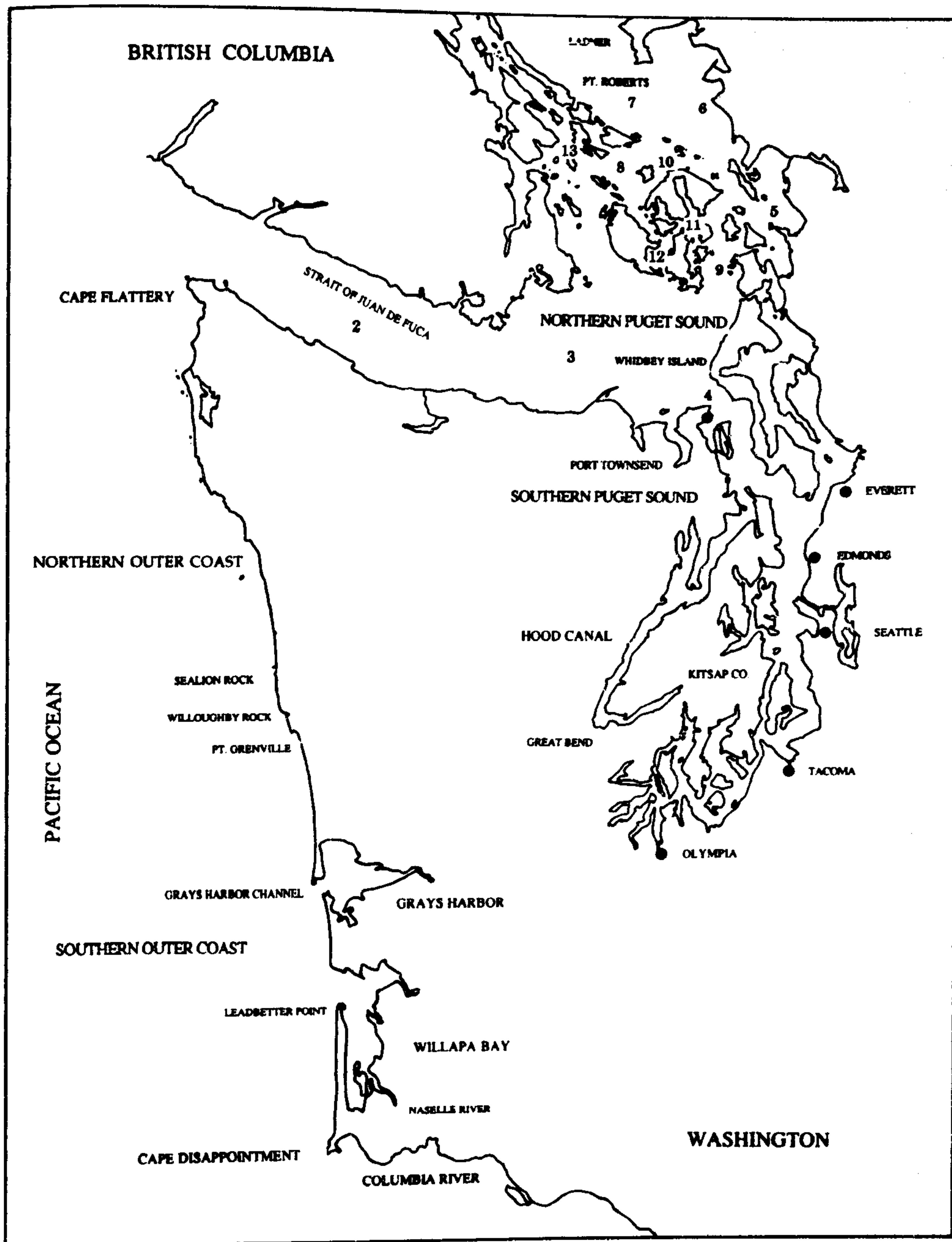


FIG. 1. Map of western Washington marine areas. Numbers show general locations of regions, specifically defined in Wahl et al. (1981) and Speich and Wahl (1989).

used the same methods (Speich and Thompson 1987).

Methods used to observe and quantify Marbled Murrelets on pelagic boat trips from Grays

Harbor from 1971 through 1986 were described by Wahl (1984) and those used on aerial and boat censuses in southern Puget Sound were described by Wahl and Speich (1984).

TABLE 1. Observations and densities of Marbled Murrelets on censuses of nearshore waters near Sea Lion Rock, coastal Washington.

Date	Number cen- suses ^a	Total area (km ²)	Number of birds observed	Density (birds/ km ²)	
1984					
Apr	8-14	4.4	8.80	0	0.00
	15-21	11.8	23.62	0	0.00
	22-28	10.3	20.61	0	0.00
	29-05	13.4	26.89	19	0.71
May	6-12	4.6	9.30	2	0.22
	13-19	15.0	30.16	31	1.03
	20-26	6.4	12.82	26	2.03
	27-02	8.9	17.84	6	0.34
June	3-9	9.6	19.35	1	0.05
	10-16	17.5	35.18	0	0.00
	17-23	2.0	4.02	7	1.74
	24-30	1.6	3.27	3	0.92
Jul	1-7	3.3	6.53	5	0.77
	8-14	0.9	1.76	6	3.41
	15-21	4.6	9.30	4	0.43
	22-28	0.5	1.01	0	0.00
1985					
Apr	7-13	1.0	2.01	0	0.00
	14-20	4.0	8.04	0	0.00
	21-27	0.9	1.76	0	0.00
	28-04	6.5	13.07	7	0.54
May	5-11	2.9	5.78	0	0.00
	12-18	4.0	8.04	0	0.00
	19-25	3.4	6.79	2	0.29
	26-01	10.5	21.11	8	0.38
Jun	2-8	1.8	3.52	9	2.56
	9-15	2.8	5.53	46	8.32
	16-22	3.5	7.04	19	2.70
	23-29	4.0	8.04	8	0.12
	30-06	—	—	—	—
Jul	7-13	2.0	4.02	20	4.98
	14-20	1.0	2.01	128	63.69
	21-27	2.0	4.02	3	0.75
	28-03	—	—	—	—
Aug	4-10	1.0	2.01	2	1.00
	11-17	—	—	—	—
	18-24	1.0	2.01	10	4.98
	25-31	3.0	6.03	19	3.15

^a Census area composed of eight radial zones not all of which were always censused on any given "census."

In a study of marine bird populations in northern Puget Sound in 1978 and 1979, we recorded all birds observed during censuses in 13 regions and 73 subregions (Wahl et al. 1981). Subregions were created (often arbitrarily) to describe geographical or biological units (see Wahl et al. [1981]). Observations in each subregion were made during aerial, boat, ferry, and/or land based censuses of specific marine water areas (as described in Wahl et al. [1981], Speich and Wahl [1986]). Censuses were combined within time

periods, such as April and May, June, July through October, and November through March. Censuses within subregions were either of shoreline habitats, generally areas next to shore and less than 20 m deep, or of open water habitats, generally areas away from shore and greater than 20 m deep. The sum of all Marbled Murrelets was divided by the total area surveyed by all census methods, including replicate censuses of individual segments, broken down by habitat, season and subregion to obtain densities. Densities were multiplied by the total area of the habitat types they represented in respective subregions to obtain projected totals.

Population estimates

Not all adult birds were present on the water during censuses in the breeding season (April-July), and not all birds present were breeding adults. The activities of Marbled Murrelets that influence their presence on the water (i.e., incubation, and attending young at the nest during the day) vary each month. The spring period (April-May) likely corresponds to pre-incubation and incubation periods in the study area (summarized in Jewett et al. [1953], Sealy [1974], Carter [1984]). June probably is when most Marbled Murrelets are breeding (e.g., incubating eggs and rearing young; Sealy 1974, Carter 1984), and when young birds start to appear on the water (Bowles 1911). During July, some birds are incubating, some are feeding young, and many chicks are fledging (McMannama 1950, Jewett et al. 1953, Sealy 1974, Carter 1984, Carter and Sealy 1987). Thus, any period chosen for censusing has its limitations due to the protracted breeding season length.

Because the numbers of Marbled Murrelets observed were variable, we considered it was best to use as much information as possible to derive numbers, especially since not all areas were surveyed at the same time of the season or day and since there were several different census methods employed. When timing of breeding and adequacy of censusing were both considered, we thought that the April-July time period in 1978-1979 was most appropriate for determining Marbled Murrelet numbers. We thought, however, the April-May time period in 1978-1979 was also acceptable.

We determined projected total numbers (PT) of Marbled Murrelets during the breeding season for the study area using:

TABLE 2. Observations and densities of Marbled Murrelets on boat transects in nearshore waters of the Washington northern outer coast.

Location	Survey date	Survey length (km ²)	Survey area (km ²)	Number observed	Density (birds/km ²)
LaPush-Alexander Island	6-01-78	11.0	3.3	14	4.24
Alexander Island-LaPush	6-02-78	11.5	3.45	8	2.32
LaPush-Carroll Island	6-08-78	12.5	3.75	19	5.07
Makah Bay-Carroll Island	6-27-78	38.0	11.4	34	2.98
LaPush-Carroll Island, return	7-22-78	24.0	7.2	5	0.21
Kalalock-Destruction Island	6-11-79	18.0	5.4	25	4.63
Sea Lion Rock-Pt. Grenville	6-12-79	18.0	5.4	22	4.07
LaPush-Destruction Island	7-24-79	28.0	4.2	35	8.33
Destruction Island-Alexander Island	7-26-79	14.0	4.2	10	2.38
Pt. Grenville-Tunnell Island	6-11-85	43.2	13.0	92	7.09
Pt. Grenville-Tunnell Island	7-09-85	43.5	13.1	6	0.44
Mean totals		261.7	74.3	270	3.63

$$PT = [I(1 - S) + S]A, \quad \text{[Equation 1]}$$

where, A is the total population (i.e., breeding adults plus subadults but excluding juveniles) of the study area, S is the proportion A that is composed of nonbreeding subadult birds (0.15) (Sealy 1975), $1 - S$ is the proportion of A that are breeding adults (0.85), and I is the proportion of the breeding adults not at the nest incubating or attending young (first few days after hatching) on any given census. We used an approximate value of 0.75 for I (derived as the average of, 0.5 present during incubation [April-June] and 1.0 present during chick period [June-July], after Carter [1984] and Sealy and Carter [1984]).

We determined A as:

$$A = PT/I(1 - S) + S, \quad \text{[Equation 2]}$$

or,

$$A = PT/0.84. \quad \text{[Equation 3]}$$

RESULTS

Numbers of Marbled Murrelets

Northern outer coast. — Summer. — Marbled Murrelets were recorded in nearshore waters at all three shore stations at the south edge of this area (Speich et al. 1987). Birds were often observed in the Sea Lion Rock census area in 1984 and 1985, with more birds observed more often in 1985 (Table 1). The timing of occurrence and numbers of Marbled Murrelets were highly variable in this small nearshore area, but murrelets did occur over most of the summer in both years.

Nearby, in the Willoughby Rock census area, fewer birds were observed less often, and still fewer were observed in the Point Grenville census area. Densities calculated from boat censuses ranged from 0.4 to 8.3 birds/km² (Table 2). Using the mean density of 3.6 birds/km², we calculated a total of about 1,600 Marbled Murrelets during summer in this nearshore area (444 km²).

Winter. — Only 10 Marbled Murrelets were observed on the 19 November 1979 coastal flight, resulting in a density of 0.25 birds/km². Applying this density to the nearshore area, we calculated that about 110 Marbled Murrelets were present. However, because of the small sample, only the presence of small numbers of Marbled Murrelets can be stated.

Southern outer coast. — Summer. — Waterbirds in the Columbia River, its mouth and nearshore plume, and the nearshore waters north to the mouth of Grays Harbor were surveyed on 13 April 1984, after the March 1984 Columbia River oil spill (Speich and Thompson 1987, unpubl. obs.). Only three Marbled Murrelets were detected, all in the mouth of the Columbia River at river miles zero to five. This gives a density of 2.8 birds/km², and an estimate of about 70 Marbled Murrelets in the 24 km² mouth of the river. In March through August 1980, Marbled Murrelets were not observed during censuses in the mouth of the Columbia River (Hazel 1981). On 13 April 1984 no murrelets were observed on either 31 km of aerial transects west and east from the mouth of the Columbia River or on aerial transects in nearshore waters north to the mouth of Grays Harbor.

Number Birds	367	247	63	0	2	0	0	0
Number Transects	90	93	129	140	302	216	42	16
Total Length (km)	627	673	1160	1304	2891	1433	194	36

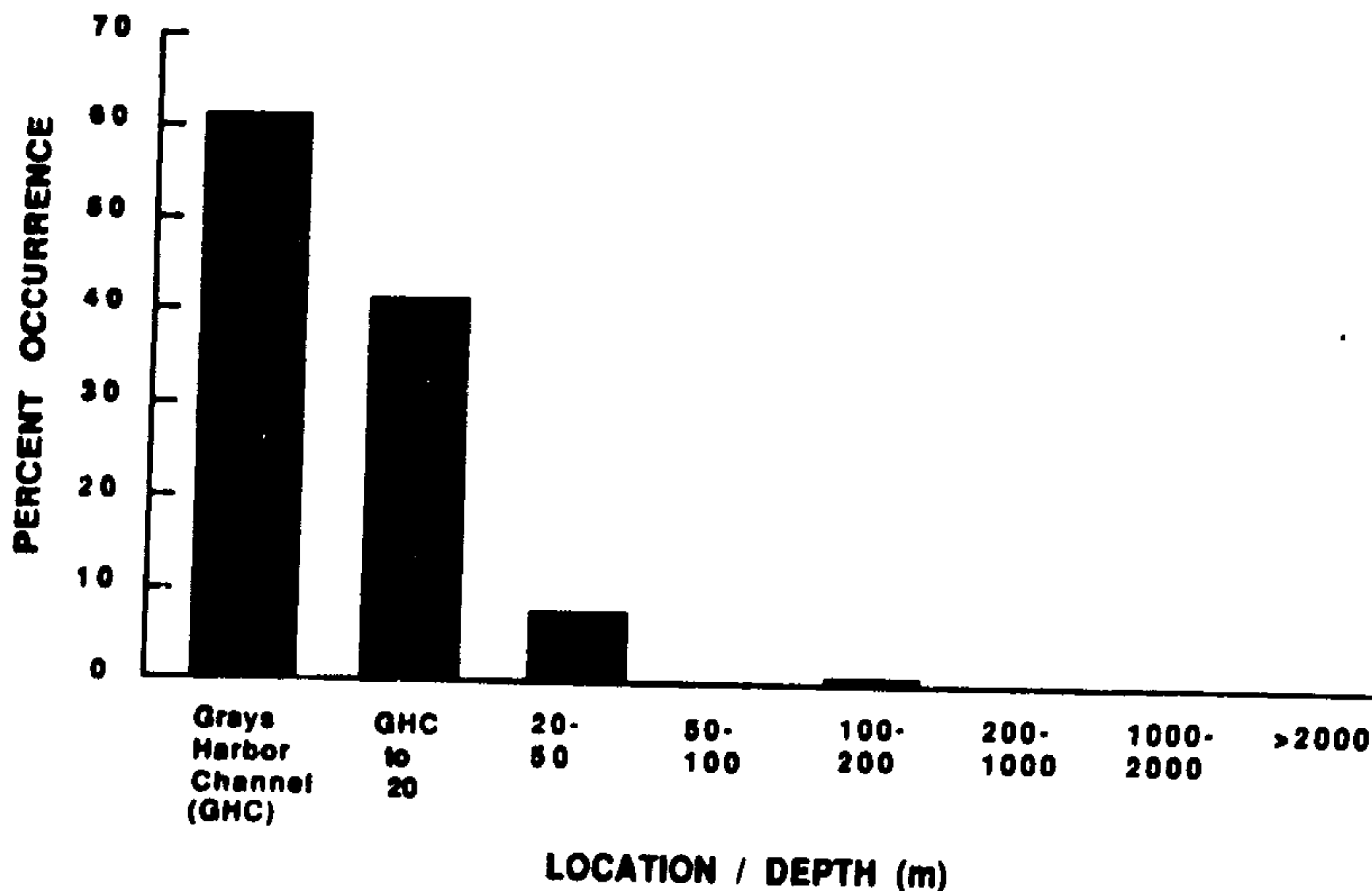


FIG. 2. Occurrence of Marbled Murrelets as a function of water depth. Total numbers of birds observed, total number of transects performed, and total length (km) of transects are shown at top of bars. Data from observations of murrelets on boat transects of coastal waters off Grays Harbor, Washington, April through July, 1971-1989 (Wahl, unpubl. data).

From spring through fall 1971 to 1989, Marbled Murrelets were consistently observed in the Grays Harbor Channel and nearshore off Grays Harbor, but were generally absent from deeper and farther offshore waters (Fig. 2). During this same period, numerous single and paired birds were observed on occasional boat transects near shore north of this area.

Although there have been no systematic censuses of waterbirds in Grays Harbor and Willapa Bay, numbers of Marbled Murrelets there are apparently low. Only small numbers of birds were observed at the mouth of the Naselle River in Willapa Bay (J. Atkinson, pers. comm.), and small numbers were often observed off the north end of Grassy Island, near Leadbetter Point, in the mouth of Willapa Bay. However, murrelets were reported by fishermen as common in Willapa Bay (R. Widrig, unpubl. notes, Manuscript Collection, Suzallo Library, Univ. Washington, Seattle).

Overall, we roughly estimate that fewer than 500 Marbled Murrelets are present in this area during the breeding period.

Winter.—Little is known of the distribution and numbers of Marbled Murrelets present during the winter. Five murrelets were observed on the 19 November 1979 flight from the mouth of Grays Harbor to the north along the coast. Two Marbled Murrelets were reported on only two of 14 Leadbetter Point Christmas Bird Counts from 1973 to 1986. A total of 74 Marbled Murrelets were observed on nine of 13 Grays Harbor Christmas Bird Counts from 1972 to 1986. Small numbers of Marbled Murrelets were observed in Grays Harbor Channel (10 passages through channel, 45 birds observed) and near its mouth (27 birds in water <20 m depth, and 10 in water just >20 m depth) during winter (November–March) pelagic trips. All that can be said is that murrelets are known to be present in this region during the winter, but abundance and pattern of distribution remain uncertain. The only exception is the small number often found in the vicinity of Grays Harbor Channel.

Southern Puget Sound.—Although reports of waterbirds in this area date back to 1792 (Menzies [1792]), Baird et al. (1860:915) first reported

the Marbled Murrelet, as "... probably constantly resident in the latitude of Puget's Sound." They mentioned specimens secured in Puget Sound by J. G. Cooper, G. Suckley, and others, in the 1850's. These and other subsequent reports of sightings of Marbled Murrelets (e.g., Dawson and Bowles 1909, Rathbun 1915, Jewett et al. 1953), do not permit numbers to be estimated. Only recent surveys of southern Puget Sound have provided such estimates.

Summer.—In May and June 1982, Wahl and Speich (1984) surveyed all of southern Puget Sound, Hood Canal and the waters east of Whidbey Island. They observed 406 Marbled Murrelets, in small numbers throughout the area, but less often observed in southern reaches of the area than in northern areas.

Winter.—Data from Christmas Bird Counts (Edmonds, Everett, Kitsap County, Olympia, Port Townsend, Seattle, and Tacoma; see *Audubon Field Notes* and *American Birds*, 1951–1986) showed that Marbled Murrelets were consistently found in southern Puget Sound during the winter, but that numbers varied between years and count areas. Christmas Bird Count totals and winter aerial censuses (Wahl and Speich 1983, unpubl. obs.) indicated that winter numbers of Marbled Murrelets were likely lower in southern than northern Puget Sound. Birds were widely distributed, but were often concentrated, for example at the entrance to Hood Canal and the Great Bend of Hood Canal.

Northern Puget Sound.—Marbled Murrelets often have been reported from this area (e.g., Rhoads 1893, Edson 1929, Jewett et al. 1953), but numbers were not quantified. Marbled Murrelets occurred throughout the area in all regions and subregions during censuses conducted in 1978 and 1979 (Manuwal et al. 1979, Wahl et al. 1981, Speich and Wahl 1986).

Spring-Summer.—During 1978 and 1979, there were about 3400 sightings of Marbled Murrelets on 416 (16.3%) of 2558 censuses in April–July (Appendix 1). The sum of projected totals for all nearshore and offshore areas of all subregions was 1800 birds (Table 3).

Applying Equation 3, the total population for this period was 2100 birds (Table 3). The projected total for spring (April–May) 1978–1979 was 1600 birds or a total population of 1900 birds; however, Equation 3 is less appropriate for this period because I is closer to 0.5 at this time. Numbers for June 1978–1979 (projected total = 2400, total population = 2900), July 1978

TABLE 3. Total numbers of Marbled Murrelets in Washington marine waters, spring–summer (April–July) and winter (November–March), 1978 to 1989.

Location Observation period	Projected totals	Total popula- tion
Northern outer coast		
Apr–Jul	1,600	1,900
Nov–Mar	Present	
Southern outer coast		
Apr–Jul	< 500	< 500
Nov–Mar	Present	
Southern Puget Sound		
Apr–Jul	406	480
Nov–Mar	> 400	
Northern Puget Sound		
Apr–Jul	1,800	2,100
Nov–Mar	3,400	
Total (spring–summer only)	4,300	5,000

(1100 and 1300, respectively), and July 1979 (600 and 700) vary considerably from these numbers, perhaps due to the small number of censuses and incomplete censusing of the 73 subregions in the smaller time periods.

Winter.—During the winter periods of 1978 (January–March), 1978–79 (November–March) and 1979 (November–December), there were 3962 observations of Marbled Murrelets on 580 (22.2%) of 2618 censuses (Appendix 2). The sum of the projected totals for all shoreline and offshore areas of all subregions for the winter periods was about 3400 birds (Table 3); also the total population, as winter projected totals, unlike those for the spring–summer period, were not adjusted.

Seasonal changes in numbers

Three early reports noted seasonal changes in the abundance of Marbled Murrelets in Puget Sound: Edson (1908:429) stated that murrelets were "Abundant in winter and fairly common in summer . . ."; Rathbun (1915:461) stated that they were "From November until April a common resident, becoming rarer as the season progresses . . ."; and Miller et al. (1935:59) stated that they were "More numerous in winter." Only recent data from northern and southern Puget Sound can be used to determine marked seasonal changes in the numbers of Marbled Murrelets.

Southern Puget Sound.—With relatively thorough (mainly boat) coverage of southern Puget Sound, Hood Canal, and waters east of Whidbey

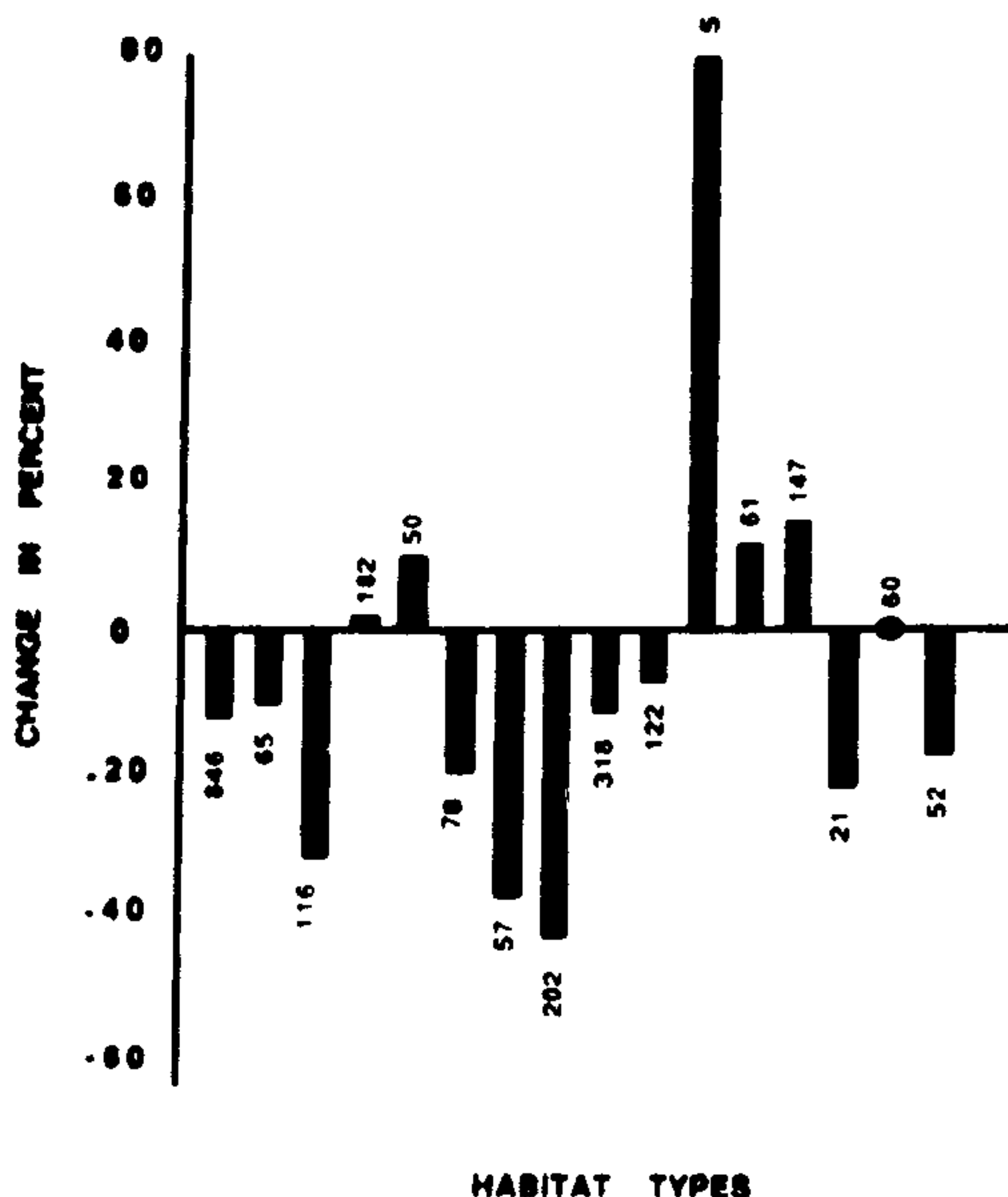


FIG. 3. Changes in percent of censuses with Marbled Murrelets detected, winter (November–March) compared to spring-summer (April–July), in 12 regions of northern Puget Sound, 1978 and 1979. Total number of censuses performed in each region is shown above/below each column. Region boundaries and descriptions are found in Wahl et al. (1981).

Island, in summer, Wahl and Speich (1984) observed 406 birds. Whereas aerial censuses detected a smaller proportion of birds actually present, winter flights suggested somewhat greater numbers than in spring-summer. On one flight, 220 birds were observed in Hood Canal, of which 190 were in the Great Bend subregion alone. Certain Christmas Bird Counts which cover similar areas to those done by boat during summer (e.g., Olympia) also indicated more Marbled Murrelets present in winter (range 9–85 birds, $\bar{x} = 32$, $n = 6$ counts) than in summer (9 birds, 1 boat count).

Northern Puget Sound.—It is very likely that more Marbled Murrelets occur in northern Puget Sound during winter than at other times. Seasonal differences in densities and percent of censuses reporting Marbled Murrelets were found: more birds were observed and a greater proportion of censuses encountered murrelets during the winter periods (compare subregion data in Appendices 1 and 2 for examples). In summary, this trend is reflected in that eight of the 12 geographic regions of northern Puget Sound (Wahl et al. 1981) had more censuses with Marbled

Murrelets present in winter periods as compared to spring-summer periods (Fig. 3). Projected totals for the winter periods of 1978 and 1979 were somewhat higher than the total population estimated for the spring-summer periods of 1978 and 1979 (Table 3). These trends are contrary to those expected if the population was stable, as generally poorer winter observation conditions would reduce the portion of birds present that are observed. Thus, the magnitude of the reported increases are likely conservative.

Other observations also indicate that Marbled Murrelets in northern Puget Sound are more common during winter than spring-summer. The projected total number of Marbled Murrelets in winter was 3400 birds when birds were found in nearly all subregions of northern Puget Sound (Appendix 2), and since we assume that all birds are in marine waters at this time of year, the projected total equals the total population. However, at dawn on 19 January 1978, 5200 Marbled Murrelets were observed flying south, passing Point Roberts at the northern edge of the study area (Fig. 1; Wahl et al. 1981). Although this number was low, as birds already were passing by when the observations started, the total number of birds observed was greater than the projected total number of Marbled Murrelets for all of northern Puget Sound during this time period. In addition, there have been several reports from Christmas Bird Counts and in *American Birds* (formerly *Audubon Field Notes*), and elsewhere, of concentrations of Murrelets numbering in the low thousands or hundreds in Washington marine waters during the winter. For example, Jewett et al. (1953) reported 1000 birds near Port Townsend in winter and 2125 were reported at Point Roberts in the winter of 1975–76 during the Ladner, British Columbia, Christmas Bird Count (just north of the Washington-British Columbia border). Such large numbers of birds have never been reported in summer at these or other localities in Washington.

Historical changes in numbers

Early reports of Marbled Murrelets in Puget Sound described them as “common” (Rathbun 1915, Miller et al. 1935), “abundant” (Rhoads 1893, Edson 1908), or “numerous” (Miller et al. 1935). Others reported only the presence of Marbled Murrelets in Puget Sound (Edson 1929, Gove 1946, McMannama 1950). Unfortunately, early observations were not quantified and therefore cannot be compared with recent censuses (Wahl

and Speich 1983, 1984). However, G. Alcorn (pers. comm.) and J. Slipp (pers. comm.), who lived, collected, and observed in Puget Sound for parts of the first half of this century, and who have each published papers on Puget Sound birds, both thought Marbled Murrelets were previously more abundant. We cannot now describe Marbled Murrelets as abundant, or even numerous, on Puget Sound. Marbled Murrelets are now only locally common at different times of the year, including spring and summer (Speich and Wahl, unpubl. obs.; Wahl and Paulson 1981; Lewis and Sharpe 1987).

DISCUSSION

Our analyses indicate that there was a total population of about 5000 Marbled Murrelets in the marine waters of Washington during the period April through July (Table 3). Census data for northern Puget Sound has clearly indicated that at least some Marbled Murrelets from outside the study area (presumably British Columbia) move into Puget Sound during the winter months to account for the larger numbers at that time. If part of the Washington population is migratory and leaves during winter, then even more migrants may immigrate into the state than is indicated by these numbers alone.

There are several limitations to our method of deriving population estimates. First, in extending densities, calculated from average counts of limited sampling of a habitat to the entire habitat, we assume that samples are representative of the entire habitat. However, murrelets are known to have clumped at-sea distributions with aggregations occurring where prey are concentrated (Carter 1984, Sealy and Carter 1984). Thus, all areas would not have similar densities of Marbled Murrelets as we have assumed. However, finding specific murrelet aggregations was difficult because censuses were not replicated immediately, nor were censuses by different methods done simultaneously. Some censuses were replicated within a few days, but aggregations of murrelets were not found in the same specific census tracks, even though consistent seasonal concentrations were evident within a number of subregions (also see Carter [1984]).

Second, on open waters different census methods (e.g., boats versus aircraft) sample bird populations differently and all birds present are not observed (see Briggs et al. [1985a, b]). Observation conditions in Puget Sound with its myriad of shorelines, bays, coves, islands, straits and

passages, and constantly changing environmental conditions, were often less than ideal (Wahl et al. 1981), especially for Marbled Murrelets. Unfortunately, we cannot quantify the large percentage of cryptically-colored murrelets present that we think we may not have seen during aerial censuses, especially near shore where frequent aircraft turns, reflections and shadows occurred.

Lastly, applying different census methods, levels of censusing effort, and combining censuses over large time periods and different times of day contributed to imprecision of our estimates. However, we thought that it was most important to increase our sample size as much as possible to account for variation in murrelet numbers.

Even after the intensive censusing effort in 1978 and 1979 in northern Puget Sound (Wahl et al. 1981), we can only approximate numbers of Marbled Murrelets. In future investigations, census methods should be tailored for the observation of murrelets at sea and designed to estimate their numbers more specifically. It is critical that baseline numbers using such a new census technique be obtained in the near future.

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APPENDIX 1. Abundance of Marbled Murrelets in the marine waters of northern Puget Sound and adjacent waters, spring-summer (April-July) 1978 and 1979 (Wahl et al. 1981).

Regions/sub-regions			Censuses					
No.	Water type ^a	Area (km ²) ^b	Number	% with Murrelets	Survey area (km ²)	No. birds	Density (birds/km ²)	Projected totals
1	O	841	2	0	6	0	0.00	0
2-1	O	1,884	13	0	71	0	0.00	0
2-2	S	52	7	0	6	0	0.00	0
2-3	S	5	28	4	12	2	0.17	1
2-4	S	5	10	20	45	26	0.58	3
2-5	S	13	45	68	25	13	0.52	7
2-6	S	3	23	17	45	49	1.09	3
2-7	S	21	39	8	62	7	0.11	2
2-8	S	1	21	29	15	44	2.99	3
2-9	S	9	25	12	16	7	0.44	4
Subtotal		1,992	213	10.3				23
3-1	O	1,631	41	15	346	23	0.07	108
3-2	S	0	39	23	87	50	0.58	<1
3-3	S	10	21	14	178	20	0.11	1
3-4	S	24	53	38	162	791	4.89	117
3-5	S	4	21	48	16	79	4.88	20
3-6	S	12	45	16	223	13	0.06	1
3-7	S	21	19	0	27	0	0.00	0
3-8	S	12	26	4	87	4	0.05	1
3-8	O	2	9	0	5	0	0.00	0
3-9	S	5	11	45	13	51	3.92	19
3-10	S	3	13	0	14	0	0.00	0
3-11	S	13	19	11	154	2	0.01	0
3-11	O	24	12	0	18	0	0.00	0
3-12	S	11	8	1	9	2	0.21	2
3-13	S	21	8	25	24	13	0.54	11
3-14	S	0	7	0	2	0	0.00	0
3-15	S	6	18	56	73	55	0.75	4
3-16	S	9	79	9	29	160	5.46	5
3-17	S	4	24	17	22	13	0.59	2
3-18	S	7	0	0	0	0	0.00	0
Subtotal		1,819	473	18.4				335
4-1	S	16	38	8	74	4	0.05	1
4-1	O	25	25	12	119	6	0.05	1
Subtotal		41	63	9.5				2
5-1	S	5	60	7	27	9	0.34	2
5-1	O	69	26	12	22	8	0.36	25
5-2	S	10	4	100	4	33	7.67	78
5-3	O	12	8	25	92	6	0.07	1
5-4	S	55	22	55	621	125	0.20	11
5-4	O	25	11	0	10	0	0.00	0
5-5	S	29	9	22	171	87	0.51	15
5-5	O	37	25	28	50	44	0.87	32
5-6	S	36	40	35	391	77	0.20	7
5-6	O	122	37	5	39	4	0.10	13
5-7	S	16	12	83	97	368	3.81	61
Subtotal		416	254	23.6				245
6-1	S	17	9	11	111	3	0.03	<1
6-1	O	8	18	6	8	1	0.12	1
6-2	S	14	77	25	168	137	0.81	12
6-3	S	9	12	33	97	7	0.07	1
6-3	O	10	9	0	4	0	0.00	0
6-4	S	10	33	15	37	44	1.20	11
6-5	O	13	23	39	244	51	0.21	3
6-6	S	75	5	40	2	6	4.06	300
6-6	O	82	10	40	19	40	2.11	173
6-7	S	5	50	6	31	13	0.42	2
6-7	O	29	10	10	3	2	0.59	17
6-8	O	288	40	20	33	29	0.87	251
Subtotal		560	296	19.3				771

APPENDIX I. Continued.

Regions/sub-regions			Censuses		Survey area (km ²)	No. birds	Density (birds/km ²)	Projected totals
No.	Water type ^a	Area (km ²) ^b	Number	% with murrelets				
7-1	S	16	29	34	49	131	2.68	44
7-2	S	6	36	8	9	3	0.34	2
7-3	O	365	33	21	276	48	0.17	64
Subtotal		387	98	20.4				110
8-1	S	10	53	8	18	48	2.70	26
8-1	O	329	12	0	7	0	0.00	0
8-2	S	5	50	2	43	1	0.02	<1
8-2	O	219	34	0	116	0	0.00	0
Subtotal		563	149	1.0				26
9-1	S	11	76	47	163	242	1.48	16
9-1	O	112	75	20	239	35	0.15	16
9-2	S	4	97	5	25	11	0.44	2
9-2	O	79	18	0	11	0	0.00	0
9-3	S	3	45	18	25	34	1.34	4
9-3	O	89	18	6	15	2	0.13	12
Subtotal		299	329	19.8				50
10-1	S	3	25	8	14	4	0.29	1
10-1	O	100	29	10	15	5	0.34	34
10-2	S	2	11	27	9	10	1.16	2
10-2	O	48	6	0	2	0	0.00	0
Subtotal		154	71	11.3				37
11-1	S	1	15	0	2	0	0.00	0
11-1	O	13	24	8	90	3	0.03	<1
11-2	S	3	11	0	15	0	0.00	0
11-2	O	33	48	10	244	12	0.05	2
11-3	S	5	29	7	24	4	0.17	1
11-3	O	44	23	9	59	8	0.14	6
11-4	S	3	22	45	97	41	0.42	1
11-5	O	9	24	17	62	12	0.20	2
11-6	S	2	16	44	45	17	0.38	1
11-6	O	31	114	11	240	32	0.13	4
11-7	S	3	5	20	3	1	0.33	1
11-8	S	5	31	26	91	17	0.19	1
Subtotal		146	362	14.9				19
12-1	S	6	28	0	22	0	0.00	0
12-2	S	2	32	0	33	0	0.00	0
12-3	S	8	6	50	8	10	1.28	10
12-3	O	8	4	50	4	4	0.91	7
12-5	S	2	3	0	5	0	0.00	0
12-6	S	5	9	22	18	6	0.34	2
12-7	S	2	2	100	4	4	1.00	2
12-8	S	9	2	0	9	0	0.00	0
12-9	S	3	4	0	23	0	0.00	0
12-9	O	27	1	0	16	0	0.00	0
12-10	S	24	4	75	17	27	1.59	38
Subtotal		102	95	12.6				59
13-1	S	11	39	3	104	2	0.02	<1
13-2	O	143	80	5	286	5	0.02	2
13-3	O	118	36	42	148	96	0.65	76
Subtotal		271	155	12.9				78
Total		2,558	416	16.3		3,403		1,755

^a O = Open water habitats, generally areas away from shore and greater than 20 m deep; S = Nearshore water habitats, generally areas next to shore and less than 20 m deep.

^b Areas rounded to nearest whole number from values in Wahl et al. 1981.

APPENDIX 2. Abundance of Marbled Murrelets in the marine waters of northern Puget Sound and adjacent waters during the winter, (November–March) 1978 and 1979 (Wahl et al. 1981).

Regions/sub-regions			Censuses					
No.	Water type ^a	Area (km ²) ^b	Number	% with murrelets	Survey area (km ²)	No. birds	Density (birds/km ²)	Projected totals
1	O	841						
2-1	S	1,884	16	6	86	1	0.01	22
2-2	S	52	7	0	6	0	0.00	0
2-3	S	5	20	0	8	0	0.00	0
2-4	S	5	13	0	59	0	0.00	0
2-5	S	13	36	0	20	0	0.00	0
2-6	S	3	20	15	41	6	0.15	0
2-7	S	21	34	9	59	8	0.14	3
2-8	S	1	23	22	18	7	0.39	0
2-9	S	9	23	4	15	2	0.13	1
Subtotals		1,992	192	6.8				26
3-1	O	631	40	15	412	22	0.05	87
3-2	S	0	41	12	106	14	0.13	0
3-3	S	10	27	67	219	98	0.45	5
3-4	S	24	56	21	184	122	0.66	16
3-5	S	4	23	30	18	53	2.96	12
3-6	S	12	60	8	304	11	0.04	0
3-7	S	21	29	0	41	0	0.00	0
3-8	S	12	38	21	205	27	0.13	2
3-8	O	2	9	33	6	12	1.97	4
3-9	S	5	10	0	11	0	0.00	0
3-10	S	3	9	11	7	2	0.29	1
3-11	S	13	14	14	115	2	0.02	0
3-11	O	24	9	0	12	0	0.00	0
3-12	S	11	8	13	9	2	0.22	2
3-13	S	21	12	8	36	3	0.08	2
3-14	S	0	7	14	2	65	32.50	10
3-15	S	6	15	47	62	57	0.92	5
3-16	S	9	78	17	25	75	3.00	27
3-17	S	4	20	15	17	22	1.29	5
3-18	S	7	3	0	1	0	0.00	0
Subtotal		1,819	508	18.3				178
4-1	S	16	17	12	46	17	0.37	6
4-1	O	25	21	48	100	97	0.97	25
Subtotal		41	38	31.6				31
5-1	S	5	49	14	21	18	0.84	4
5-1	O	69	26	31	25	26	1.06	73
5-2	S	10	6	100	5	168	33.60	343
5-3	O	12	9	33	104	5	0.05	1
5-4	S	55	24	21	712	26	0.04	2
5-4	O	25	12	8	7	27	3.97	99
5-5	S	29	12	17	225	19	0.08	2
5-5	O	37	15	33	24	87	3.60	133
5-6	S	36	45	49	405	591	1.46	52
5-6	O	122	30	40	27	121	4.48	547
5-7	S	16	11	73	30	206	2.50	40
Subtotal		416	452	31.2				2,208
6-1	S	17	10	0	121	0	0.00	0
6-1	O	8	12	8	5	2	0.37	3
6-2	S	14	44	16	91	21	0.23	3
6-3	S	9	13	23	104	14	0.13	1
6-3	O	10	6	0	10	0	0.00	0
6-4	S	10	24	13	30	21	0.70	7
6-5	O	13	18	39	231	23	0.10	1
6-6	S	75	2	0	1	0	0.00	0
6-6	O	82	6	33	11	18	1.58	127
6-7	S	5	34	21	19	59	3.16	16
6-7	O	29	8	38	2	15	6.25	184
6-8	O	288	30	0	23	0	0.00	0
Subtotal		560	207	15.9				342

APPENDIX 2. Continued.

Regions/sub-regions			Censuses		Survey area (km ²)	No. birds	Density (birds/km ²)	Projected totals
No.	Water type ^a	Area (km ²) ^b	Number	% with murrelets				
7-1	S	16	25	44	16	152	3.74	61
7-2	S	6	9	0	5	0	0.00	0
7-3	O	365	27	33	215	34	0.16	58
Subtotal		387	61	32.8				119
8-1	S	10	45	9	19	14	0.75	7
8-1	O	329	12	8	8	1	0.13	43
8-2	S	5	40	10	28	11	0.40	2
8-2	O	219	40	3	109	2	0.02	4
Subtotal		563	137	7.3				56
9-1	S	11	52	31	68	116	1.71	18
9-1	O	112	79	19	220	37	0.17	19
9-2	S	4	96	9	27	45	1.64	6
9-2	O	79	17	6	9	2	0.22	17
9-3	S	3	36	17	18	14	0.77	3
9-3	O	89	19	5	17	2	0.12	11
Subtotal		299	299	16.1				74
10-1	S	3	24	38	14	115	8.33	27
10-1	O	100	30	3	15	2	0.13	13
10-2	S	2	14	21	14	19	0.70	1
10-2	O	48	8	25	4	7	1.84	88
Subtotal		154	76	19.7				129
11-1	S	1	16	6	2	6	3.75	4
11-1	O	13	29	24	90	120	0.78	10
11-2	S	3	19	26	36	20	0.55	2
11-2	O	33	55	36	214	1,213	0.57	19
11-3	S	5	22	14	9	12	1.28	6
11-3	O	44	19	16	17	14	0.82	36
11-4	S	3	27	85	89	274	3.08	8
11-5	O	9	13	23	21	6	0.28	2
11-6	S	2	24	21	54	10	0.18	0
11-6	O	31	143	35	227	187	0.82	25
11-7	S	3	6	67	3	8	2.67	7
11-8	S	5	30	57	72	120	1.68	2
Subtotal		146	403	34.7				121
12-1	S	6	16	0	17	0	0.00	0
12-2	S	2	38	55	27	189	6.95	10
12-3	S	8	5	0	7	0	0.00	0
12-3	O	8	4	50	4	7	1.79	13
12-5	S	2	5	0	8	0	0.00	0
12-6	S	5	9	0	19	0	0.00	0
12-7	S	2	3	67	6	9	1.50	3
12-8	S	9	3	33	13	4	0.31	3
12-9	S	3	5	40	37	7	0.19	0
12-9	O	27	2	100	31	10	0.32	8
12-10	S	24	4	50	17	13	0.76	18
Subtotal		102	94	34.0				55
13-1	S	11	36	25	76	40	0.52	6
13-2	O	143	72	13	204	18	0.09	13
13-3	O	118	43	12	123	10	0.08	10
Subtotal		271	151	15.2				29
Total		2,618	580	22.2		3,962		3,368

^a O = Open water habitats, generally areas away from shore and greater than 20 m deep; S = Shoreline water habitats, generally areas next to shore and less than 20 m deep.

^b Areas rounded to nearest whole number from values in Wahl et al. 1981.